Habitat Modeling of Marine Mammals as function of Oceanographic Characteristics; Development of Predictive Tools for Assessing and Managing the Risks and the Impacts due to Sound Emissions

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Award Number: N000141010533

LONG-TERM GOALS

Long-term goals of this research are:

1. Improving the knowledge about how ocean dynamics affect the ecology and distribution of marine mammals in different areas;

2. Developing tools to predict marine mammal presence probability or density on the basis of selected environmental predictors;

3. Creating the knowledge-based decisional framework to choose among potential mitigation measures

OBJECTIVES

Three are the main scientific objectives of this research:

Objective 1. Development of methods to integrate acoustic and visual data in marine mammal distribution/density models;

Objective 2. Evaluation of the model transferability to areas different from the calibration sites;

Objective 3. Definition of the knowledge-based decision support framework for managing the impact of the noise-producing human activities.

APPROACH

Figure 1 shows the flow-chart of the tasks corresponding to the specific objectives of the research. Details about the technical approaches applied for specific research objectives are discussed below.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE **Habitat Modeling of Marine Mammals as function of Oceanographic Characteristics; Development of Predictive Tools for Assessing and Managing the Risks and the Impacts due to Sound Emissions**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Piazza Leonardo da Vinci, 32,20133 Milano, Italy.,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

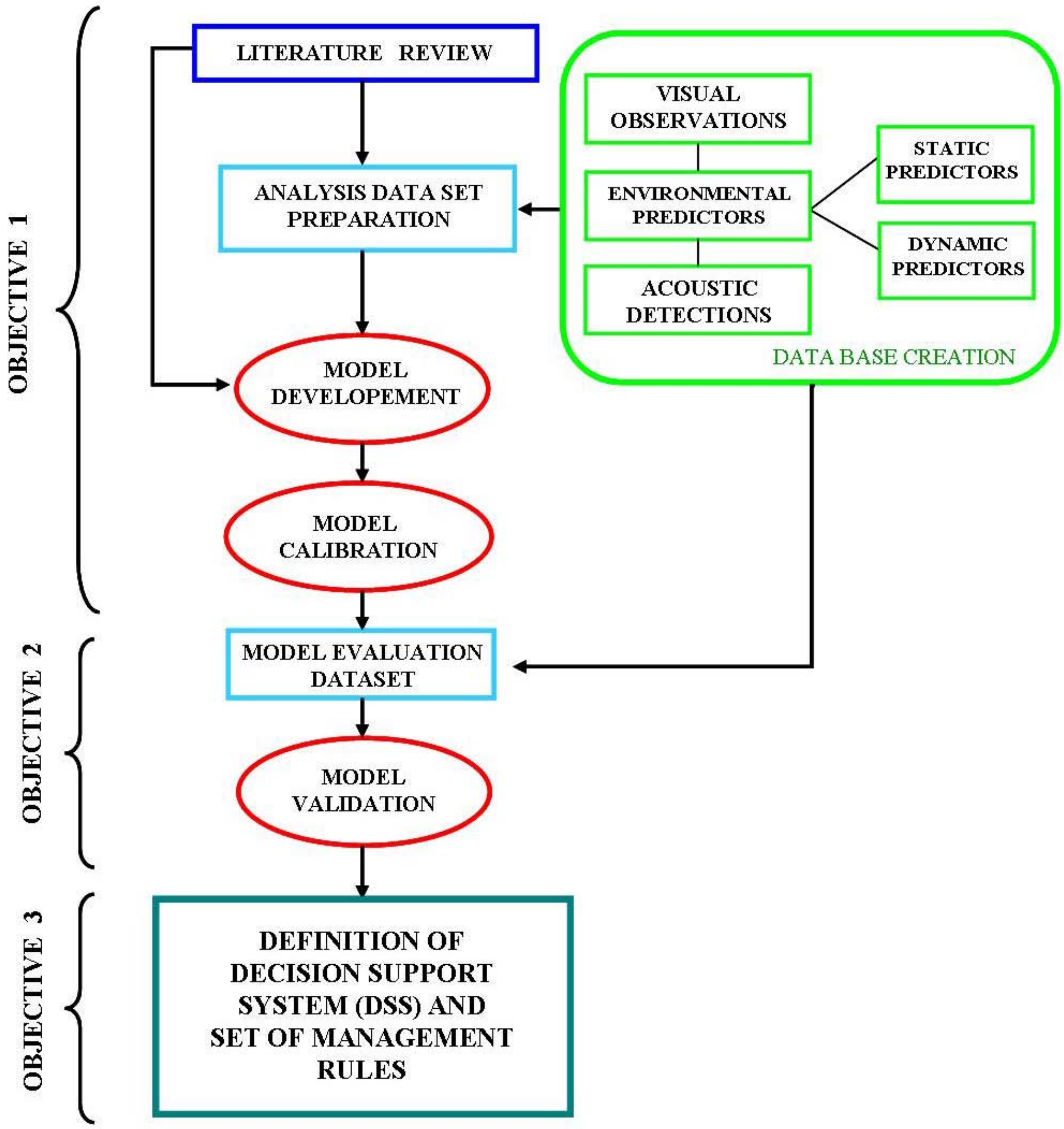

Figure 1. Research project flow-chart. Color boxes refer to specific tasks: Literature review: critical review of the statistical methods used, literature-based selection of potential response variables and predictors; Database creation: data acquisition about the species presence (i.e. visual observations, passive acoustic detections) and the environmental predictors (i.e. static predictors such as depth, slope and dynamic predictors such as temperature, salinity and chlorophyll etc.); Analysis dataset preparation: preparation of the dataset for model calibration and evaluation (i.e. validation); Modeling: calibration, best model selection, selection of the best predictors, validation, simulations to support the scenario analysis; Decision Support System: definition of the guidelines framework for choosing the appropriate set of risk mitigation alternatives.

Objective 1:
Literature review will be the basis for choosing among statistical approaches, and for selecting potential response variables and predictors. Data about the species distribution and the environmental predictors, either static (e.g. depth, seabed slope etc.) or dynamic (e.g. temperature, oxygen, chlorophyll etc.) will be organized into a global dataset to be later split into a model calibration and a model validation set.

Modeling exercises will be run for determining regions of high and low marine mammal presence or density for different case studies. Different statistical approaches (e.g. Logistic Regressions, Generalized Linear Models) will be used to model density or presence/absence patterns of target species. A methodology will be proposed to integrate acoustic and visual data in the marine mammal distribution models.

Objective 2:
The transferability of the developed models to areas different from the calibration sites will be evaluated. Model accuracy will be evaluated by examining the agreement between predictions and actual observations, using Cross-Tabulation analysis and by calculating the indices describing predictive performance of models (Lindenmayer et al., 1990; Pearce et al., 1994; 2000): the **sensitivity** (i.e. the true positive fraction, the proportion of the positive observations in agreement with the presence predictions over the total positive observations), the **specificity** (i.e. the true negative fraction, the proportion of the negative observations in agreement with the absence predictions over the total negative observations), the **false positive fraction** and the **false negative fraction** (i.e. both measuring the proportion of case when the observations and the predictions disagree).

The analysis of model results of the same species in different areas will highlight behavioral differences that may affect their distribution pattern and response to environmental predictors.

Objective 3:
Mitigation may consist of different alternatives that could be more or less appropriate from case to case. The choice among different mitigation alternatives designed to prevent, reduce or rectify the impacts of sound introduced into the marine environment should be guided by the available knowledge.

So the available knowledge needs to be organized into model-based risk assessment procedures and into a decisional framework (e.g. a DSS) which will constitute the guide to support decisions. The definition of DSS will constitute the final product of the research.

Key individuals of the research are:
Arianna Azzellino, PhD: Principal Investigator (PI)
Caterina Lanfredi: Phd student (PS)

Roles played by principal investigator (PI) and by the PhD student (PS):

PS	Literature review
PI+PS	Data acquiring and database creation
PS	Analysis data set preparation
PI+PS	Modeling (calibration, best model selection, validation, scenario analysis)
PI+PS	DSS system creation when used in areas different from the calibration site.

WORK COMPLETED

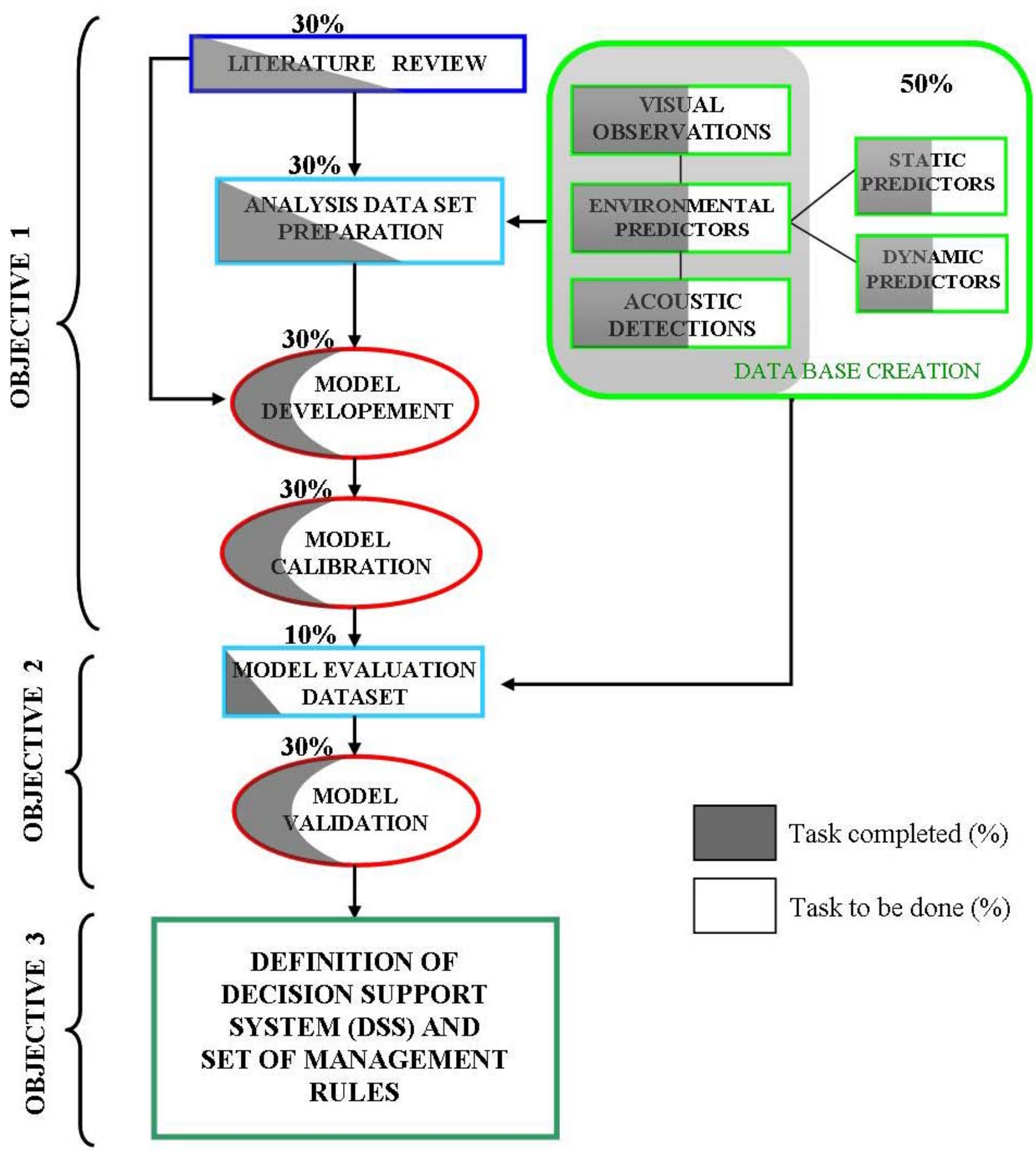

Figure 2. Research project flow-chart. Percentages of completed tasks are shown.

RESULTS

After reviewing the existing literature about habitat models, the logistic regression approach was identified as one of the most effective to analyze presence/absence data. Logistic modeling exercises were run in different areas of the Mediterranean sea, using visual observations data obtained from the NURC/Sirena databases (Figure 3). Cuvier's beaked whale was chosen as target species. The Ligurian sea area dataset was chosen for model calibration, whereas the Alboran sea dataset was used to validate the Ligurian sea models. Details of the analysis datasets considered are presented in Table 1. Topographical predictors, such as depth and seabed slope, were used as covariates within the regression models. Also remote sensed chlorophyll-a concentrations, obtained from the SeaWiFS 8 day data products, generated by the NASA Ocean Biology Processing Group, and acquired through the Giovanni system: http://disc.sci.gsfc.nasa.gov/giovanni/, were used as predictors.

Table1. Analysis database used for the modeling exercise. Transferability to Alboran area (validation site) of the developed model in the Ligurian area (calibration site) was tested.

LIGURIAN SEA				**ALBORAN SEA**
NURC Trials	**Sirena 01**	**Sirena 02**	**Sirena 03**	**Sirena 08**
Time Period	*17-Sep 7-Oct*	*5 - 23 July*	*25-Aug 12-Sep*	*17 May - June 18*
Research Vessels	*NRV Alliance ITS A. Magnagni T-boat Manning*	*NRV Alliance*	*NRV Alliance ITS A. Magnagni CRV Leonardo RV Urania*	*NRV Alliance*
Positve Effort * (km)	*2339.39*	*1700.54*	*3401.03*	*504*
BW sightings	*0*	*24*	*2*	*16*
BW cluster of acoustic detections	*/*	*/*	*/*	*59*
Tot. Sighting	*141*	*225*	*179*	*316*

* Km conducted with 4 visual observer and Beaufort sea state < 4

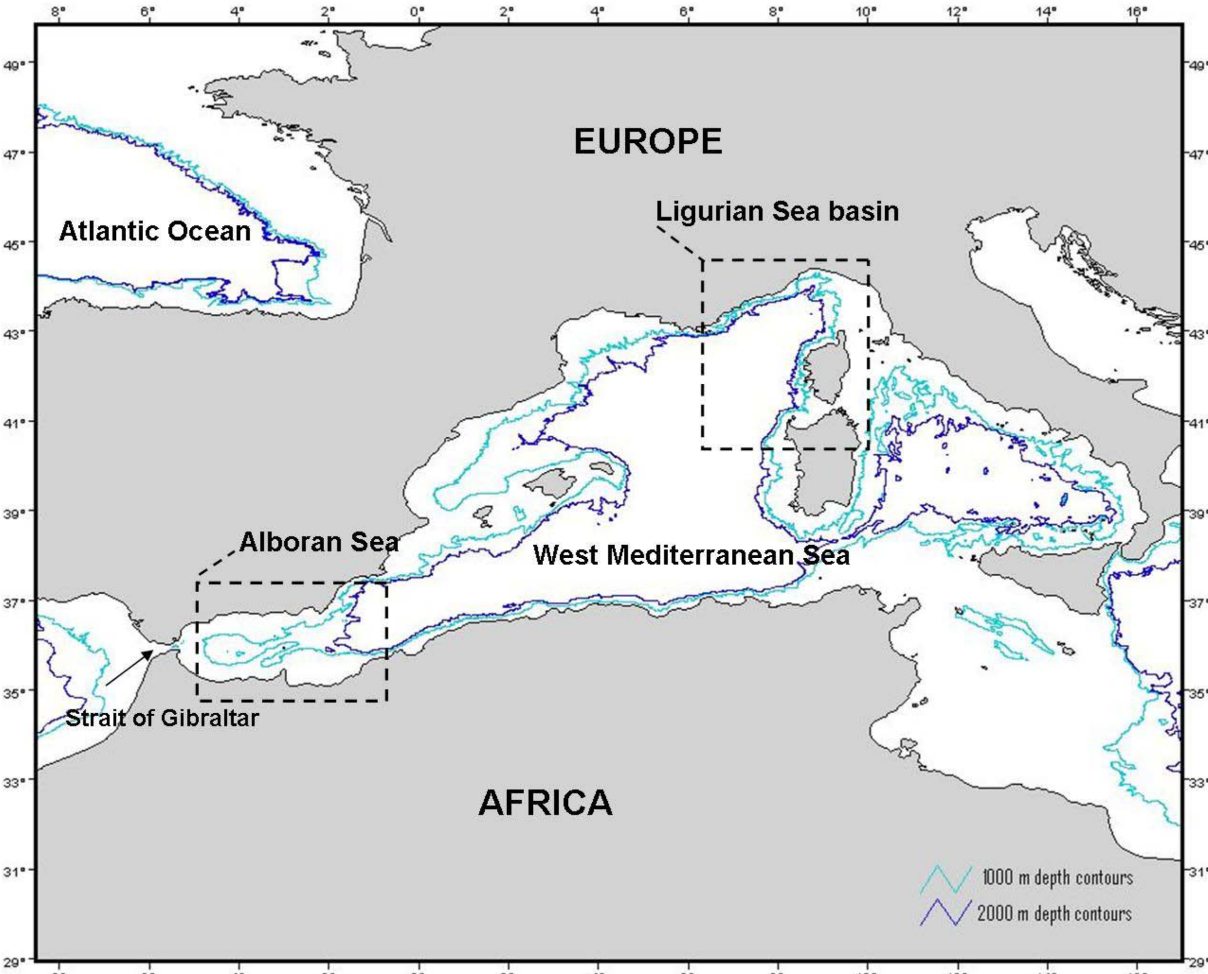

Figure 3. West Mediterranean Sea study areas. Calibration site: Ligurian Sea basin (northwestern Mediterranean Sea); Validation site: Alboran Sea (southwestern Mediterranean Sea). 1000 m (black lines) and 2000 m (grey lines) depth contours are shown.

Objective 1 (model calibration):

The classification performances of the models developed in the Ligurian Sea have been evaluated either using the chlorophyll (i.e. dynamic predictors) or the topographical features (i.e. static predictors) as predictors. The accuracy was found slightly lower for the models using the dynamic predictors rather than static predictors (i.e. 73% vs 87%). Besides the differences in accuracy, the two models showed a very good agreement in their predictions.

Objective 2 (model validation):

By using the same predictors selected for the Ligurian Sea *a priori* prediction map of presence and absence cells was produced for the Alboran Sea area. These predictions were overlaid with the Cuvier's beaked whale observations collected during the Sirena 08 cruise. The accuracy of the a priori predictions were evaluated through the analysis of sensitivity and specificity. Moreover, to increase the validation data set, the visual observations, strongly affected by unfavorable weather conditions, were integrated with acoustic detections. A significant finding of this first model exercise was the evidence that, although the models showed approximately the same accuracy for presence predictions, the

accuracy for absence predictions was found to be inversely correlated to the overall accuracy evaluated in the calibration phase. Also, it is worthwhile to point out that model predictions, either based on bathymetry or chlorophyll features, were surprisingly comparable in both the study areas.
It could be questioned that both bathymetry and chlorophyll are indirect predictors for beaked whales and how the observed patterns could be interpreted ecologically. Probably these features can be seen as proxies of the macro-scale features that indirectly outline beaked whale habitats. It is true that these proxies may not apply for different species, however, as far as beaked whales are concerned and as far as the macro-scale features involved in different study areas may be considered comparable, we believe these results as encouraging and supporting the idea that modeling tools can be employed for the preliminary risk assessment of "unsurveyed" areas.

New capabilities generated
The accuracy of the *a priori* predictions obtained from the Ligurian Sea models was found adequate for the Alboran Sea and lessons were also learnt to determine a uncertainty factor that should be applied to the model predictions when used in areas different from the calibration site.

IMPACT/APPLICATIONS

Understanding of marine mammals habitat preferences represent a critical step forward the developing of Risk Assessment tools that may help managers and sound-producers in predicting which areas support high densities and should deserve a higher protection level. Once determined the key habitat characteristics and developed the tools to estimate the probabilities of high or low density areas, it is possible to manage the estimated risks through proposing mitigations measures. This research will contribute in creating the risk-based knowledge background to choose among potential mitigation alternatives.

RELATED PROJECTS

The project entiteled "Marine Mammal Risk Mitigation Projects" conducted by NATO Undersea Research Centre (NURC) in La Spezia, Italy (http://www.nurc.nato.int/research/mmrm.htm), is closely related to this research. The analysis dataset include the NURC/MMRM database of marine mammals sighting, oceanographic parameters (CTD, XBT, XCTD) and passive acoustic detections and sound samples provided for NURC by CIBRA, Centro Interdisciplinare di Bioacustica Ricerche Ambientali University of Pavia(http://www3.unipv.it/cibra/).

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